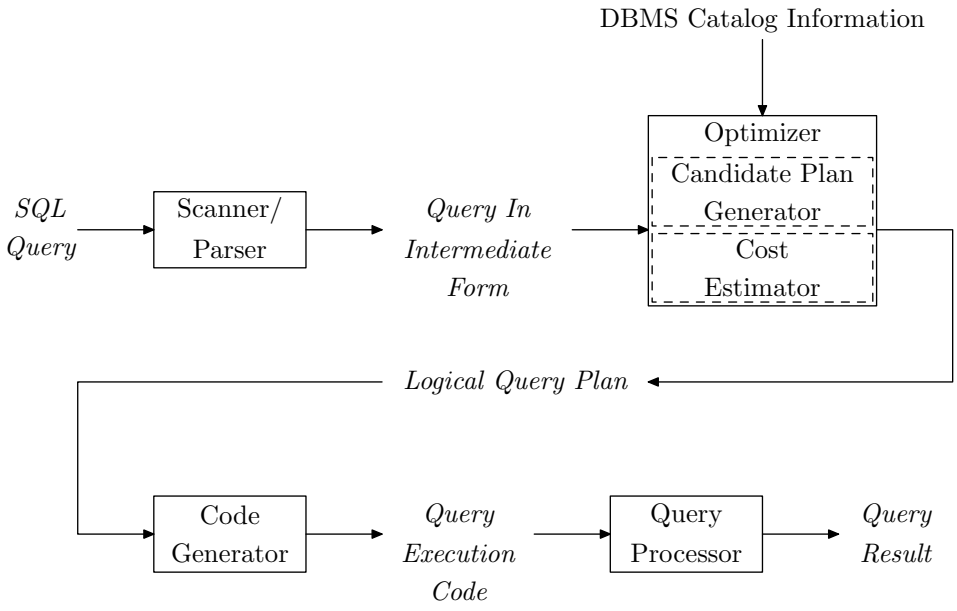
Topic 15:

Query Optimization

Lifetime of a Query



Query Trees (1 / 2)

After scanning/parsing, the query is in standard form, in which the operation order is:

Query Trees (2 / 2)

Example(s):

```
select sname
from s, p, spj
where s.sno = spj.sno
  and spj.pno = p.pno
  and status <> 0
  and pname = 'Nut';
```

Query Optimization

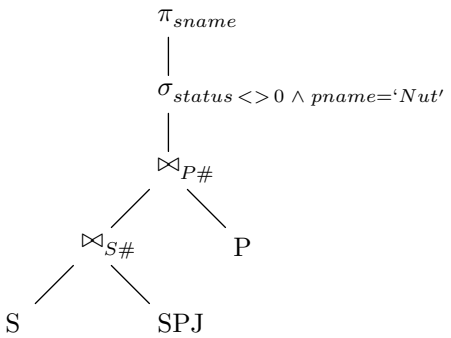
Definition: Query Optimization

Rule-based Optimization (RBO)

Idea: Apply “Rules of Thumb” that often improve execution efficiency.

Example(s): A classic: Perform selects as soon as possible.

Standard Form:



After Rule:

Cost-based Optimization (CBO)

Idea: Estimate the expense of executing each operator/algorithm

Algorithms for Project and Select

Project (π): Just one option:

Select (σ): Three main options:

Join Algorithms (1 / 5)

#1: Nested–Loops Join (NLJ)

r

X	Y
D	3
C	4
B	1
D	2

s

X	Z
D	8
B	7
D	6
A	1
B	1

Join Algorithms (2 / 5)

#2: Sort-Merge Join (SMJ)

- Precondition:

The Algorithm:

```
Make the first tuple of relation r the current tuple
Loop until one of the relations is exhausted:
    Make a set of all tuples from relation r that
     have the same join values as the current tuple
    For each tuple from relation s that has a join match:
        Output marriages of it to all set members
    The next tuple from relation r that is not a
     member of the set becomes the new current tuple
```

Join Algorithms (3 / 5)

#2: Sort-Merge Join (cont.)

Example(s): Same data as the NLJ example, but sorted on X:

r

X	Y
B	1
C	4
D	3
D	2

s

X	Z
A	1
B	7
B	1
D	8
D	6

Join Algorithms (4 / 5)

#3: Hash Join

- Idea:

The Algorithm:

```
Hash each relation using the same hash function on the
 join attributes of the tuples.
For each of the M corresponding pairs of buckets:
    Build an in-memory hash index on the contents of
     the first bucket in the pair
    For each tuple in the second bucket:
        Probe the index with its join attribute
        For each matching tuple found:
            Output the marriage
```

Join Algorithms (5 / 5)

#3: Hash Join (cont.)

Example(s): NLJ data hashed by even/odd ASCII values:

r

X	Y
D	3
C	4
B	1
D	2

s

X	Z
D	8
B	7
D	6
A	1
B	1

Examining Query Plans (1 / 2)

In Oracle 11: Prefix query with `explain plan for`.

```
explain plan for
  select sname
    from s, spj, p
   where s.sno = spj.sno
     and spj.pno = p.pno
     and status <> 0
     and pname = 'Nut';
```

And then issue the following to see the generated plan:

```
set linesize 100
set pagesize 0
select plan_table_output
  from table(dbms_xplan.display('plan_table',null,'serial'));
```

Examining Query Plans (2 / 2)

The (slightly abbreviated) Oracle 11 output:

```
Explained.
Plan hash value: 3135777751
-----------------------------------------------------------------------------------------------
| Id  | Operation                      | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT               |              |     4 |   104 |     8  (25)| 00:00:01 |
|*  1 |  HASH JOIN                     |              |     4 |   104 |     8  (25)| 00:00:01 |
|   2 |   MERGE JOIN                   |              |     4 |    56 |     4  (25)| 00:00:01 |
|*  3 |    TABLE ACCESS BY INDEX ROWID | P            |     1 |     8 |     2   (0)| 00:00:01 |
|   4 |     INDEX FULL SCAN            | SYS_C0011137 |     6 |       |     1   (0)| 00:00:01 |
|*  5 |    SORT JOIN                   |              |    24 |   144 |     2  (50)| 00:00:01 |
|   6 |     INDEX FULL SCAN            | SYS_C0011150 |    24 |   144 |     1   (0)| 00:00:01 |
|*  7 |   TABLE ACCESS FULL            | S            |     5 |    60 |     3   (0)| 00:00:01 |
-----------------------------------------------------------------------------------------------
```

Legend:

- ‘TABLE ACCESS BY INDEX ROWID’ — use index to locate tuple(s)
- ‘INDEX FULL SCAN’ — get all tuple IDs (in ascending order)
- ‘SORT JOIN’ — sorts tuples ahead of SMJ
- ‘TABLE ACCESS FULL’ — read all rows

“Vacuuming” a Database (1 / 3)

The Idea: Tell the DBMS to update what it knows about relations.

But first: Here’s how to wipe your DBMS’ mind!

In Oracle 11:

```
exec DBMS_STATS.DELETE_SCHEMA_STATS('mccann');
select count(*) from user_histograms;    ==> 0
```

In Postgres:

```
vacuum;
```

“Vacuuming” a Database (2 / 3)

Without its statistics, Oracle 11 generates a different plan:

```
Plan hash value: 2693896614
-------------------------------------------------------------------------------------------
| Id  | Operation              | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT       |              |     4 |   220 |     9  (12)| 00:00:01 |
|*  1 |  HASH JOIN             |              |     4 |   220 |     9  (12)| 00:00:01 |
|   2 |   MERGE JOIN CARTESIAN |              |     5 |   230 |     6   (0)| 00:00:01 |
|*  3 |    TABLE ACCESS FULL   | P            |     1 |    17 |     3   (0)| 00:00:01 |
|   4 |    BUFFER SORT         |              |     5 |   145 |     3   (0)| 00:00:01 |
|*  5 |     TABLE ACCESS FULL  | S            |     5 |   145 |     3   (0)| 00:00:01 |
|   6 |   INDEX FAST FULL SCAN | SYS_C0011150 |    24 |   216 |     2   (0)| 00:00:01 |
-------------------------------------------------------------------------------------------
```

Legend (cont.):

- ‘MERGE JOIN CARTESIAN’ — performs only a Cartesian Product
- ‘BUFFER SORT’ — just buffering tuples (not always a sort!)
- ‘INDEX FAST FULL SCAN’ — use multiblock reads (no ordering)

“Vacuuming” a Database (3 / 3)

We can command Oracle 11 to collect new stats:

```
exec DBMS_STATS.GATHER_SCHEMA_STATS('mccann');

select count(*) from user_histograms;    ==> 180
```

And try again:

```
Plan hash value: 3135777751
-----------------------------------------------------------------------------------------------
| Id  | Operation                      | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT               |              |     4 |   104 |     8  (25)| 00:00:01 |
|*  1 |  HASH JOIN                     |              |     4 |   104 |     8  (25)| 00:00:01 |
|   2 |   MERGE JOIN                   |              |     4 |    56 |     4  (25)| 00:00:01 |
|*  3 |    TABLE ACCESS BY INDEX ROWID | P            |     1 |     8 |     2   (0)| 00:00:01 |
|   4 |     INDEX FULL SCAN            | SYS_C0011137 |     6 |       |     1   (0)| 00:00:01 |
|*  5 |    SORT JOIN                   |              |    24 |   144 |     2  (50)| 00:00:01 |
|   6 |     INDEX FULL SCAN            | SYS_C0011150 |    24 |   144 |     1   (0)| 00:00:01 |
|*  7 |   TABLE ACCESS FULL            | S            |     5 |    60 |     3   (0)| 00:00:01 |
-----------------------------------------------------------------------------------------------
```

Back to the original plan! (Same plan hash value.)

Influencing the Query Optimizer (1 / 6)

One way to nudge the DBMS: Rewrite your queries.

Some options that influence some DBMSes:

Influencing the Query Optimizer (2 / 6)

Oracle has a different scheme: HINTS

Format: `select /*+ <hint> */ ...`

Available hints include:

- `RULE` → Use RBO instead of CBO
- `ALL_ROWS` → Favor throughput
- `FIRST_ROWS` → Favor response time
- `ORDERED` → Honor query's join order
- `USE_NL(<table(s)>)` → Use NLJ w/ `<table(s)>`
- `USE_MERGE(<table(s)>)` → Use SMJ ...
- `USE_HASH(<table(s)>)` → Use Hash Join ...

Influencing the Query Optimizer (3 / 6)

Example: RULE

```
explain plan for select /*+ RULE */ sname from s, p, spj
  where s.sno = spj.sno and spj.pno = p.pno
    and status <> 0 and pname = 'Nut';
```

```
Plan hash value: 1885933196
-----------------------------------------------------
| Id  | Operation                     | Name         |
-----------------------------------------------------
|   0 | SELECT STATEMENT              |              |
|   1 |  NESTED LOOPS                 |              |
|   2 |   NESTED LOOPS                |              |
|   3 |    NESTED LOOPS               |              |
|   4 |     TABLE ACCESS FULL         | SPJ          |
|*  5 |     TABLE ACCESS BY INDEX ROWID | P          |
|*  6 |      INDEX UNIQUE SCAN        | SYS_C0011137 |
|*  7 |    INDEX UNIQUE SCAN          | SYS_C0011142 |
|*  8 |   TABLE ACCESS BY INDEX ROWID | S            |
-----------------------------------------------------
Note
-----
   - rule based optimizer used (consider using cbo)
```


Influencing the Query Optimizer (4 / 6)

Example: ALL_ROWS

```
explain plan for select /*+ ALL_ROWS */ sname from s, p, spj
  where s.sno = spj.sno and spj.pno = p.pno
    and status <> 0 and pname = 'Nut';
```

```
Plan hash value: 3135777751
-------------------------------------------------------------------------------------------
| Id  | Operation                     | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT              |              |     4 |   104 |     8  (25)| 00:00:01 |
|*  1 |  HASH JOIN                    |              |     4 |   104 |     8  (25)| 00:00:01 |
|   2 |   MERGE JOIN                  |              |     4 |    56 |     4  (25)| 00:00:01 |
|*  3 |    TABLE ACCESS BY INDEX ROWID | P           |     1 |     8 |     2   (0)| 00:00:01 |
|   4 |     INDEX FULL SCAN           | SYS_C0011137 |     6 |       |     1   (0)| 00:00:01 |
|*  5 |    SORT JOIN                  |              |    24 |   144 |     2  (50)| 00:00:01 |
|   6 |     INDEX FULL SCAN           | SYS_C0011150 |    24 |   144 |     1   (0)| 00:00:01 |
|*  7 |   TABLE ACCESS FULL           | S            |     5 |    60 |     3   (0)| 00:00:01 |
-------------------------------------------------------------------------------------------
```

Influencing the Query Optimizer (5 / 6)

Example: FIRST_ROWS

```
explain plan for select /*+ FIRST_ROWS */ sname
   from s, p, spj
  where s.sno = spj.sno and spj.pno = p.pno
    and status <> 0 and pname = 'Nut';
```

```
Plan hash value: 2513296039
-------------------------------------------------------------------------------------------
| Id  | Operation                    | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT             |              |     4 |   104 |      8   (0)| 00:00:01 |
|   1 |  NESTED LOOPS                |              |       |       |             |          |
|   2 |   NESTED LOOPS               |              |     4 |   104 |      8   (0)| 00:00:01 |
|   3 |    NESTED LOOPS              |              |     4 |    56 |      4   (0)| 00:00:01 |
|*  4 |     TABLE ACCESS FULL        | P            |     1 |     8 |      3   (0)| 00:00:01 |
|*  5 |     INDEX FULL SCAN          | SYS_C0011150 |     4 |    24 |      1   (0)| 00:00:01 |
|*  6 |    INDEX UNIQUE SCAN         | SYS_C0011142 |     1 |       |      0   (0)| 00:00:01 |
|*  7 |   TABLE ACCESS BY INDEX ROWID| S            |     1 |    12 |      1   (0)| 00:00:01 |
-------------------------------------------------------------------------------------------
```


Influencing the Query Optimizer (6 / 6)

Example: USE_MERGE()

```
explain plan for select /*+ USE_MERGE(s,p) */ sname
   from p, spj, s
  where s.sno = spj.sno and spj.pno = p.pno
    and status <> 0 and pname = 'Nut';
```

```
Plan hash value: 2745782731
-------------------------------------------------------------------------------------
| Id  | Operation             | Name         | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT      |              |     4 |   104 |     8  (13)| 00:00:01 |
|*  1 |  HASH JOIN            |              |     4 |   104 |     8  (13)| 00:00:01 |
|   2 |   MERGE JOIN CARTESIAN|              |     5 |   100 |     6   (0)| 00:00:01 |
|*  3 |    TABLE ACCESS FULL  | P            |     1 |     8 |     3   (0)| 00:00:01 |
|   4 |    BUFFER SORT        |              |     5 |    60 |     3   (0)| 00:00:01 |
|*  5 |     TABLE ACCESS FULL | S            |     5 |    60 |     3   (0)| 00:00:01 |
|   6 |   INDEX FULL SCAN     | SYS_C0011150 |    24 |   144 |     1   (0)| 00:00:01 |
-------------------------------------------------------------------------------------
```